INFORMATION FLOW COMPARISON BETWEEN TRADITIONAL AND BIM-BASED PROJECTS IN THE DESIGN PHASE

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ABSTRACT

Project success is intimately coupled with collaborative interaction among the stakeholders and integration of information from everyone throughout the project life cycle. Building information modeling (BIM) helps translate the owner's value preposition into a successful project by enabling continuous information flow and delivering a high value product. On traditional 2D CAD projects, the information flow between the players and project stages is jumbled. However, on BIM based projects, the interaction is more flexible and overlapped where information is aggregated and shared transparently between the different users (owners, architects, structural and MEP engineers, consultants, contractors, and subcontractors).

The purpose of this paper is to understand how BIM can improve project information flow. This is accomplished by modeling interactions among participants across the conceptual and schematic design stages as opposed to the traditional process of having information silos with sub-optimal communication between various project players. In this respect, two process models are created for traditional and BIM information flow. After that, a comparison between the two models is carried out to assess the potential design process improvements resulting from the use of BIM.

The research contributes towards highlighting where failure in communication occurs and the hurdles preventing stream-lined workflow.

KEY WORDS

Building Information Modeling (BIM), Information Flow, Conceptual Design, Schematic Design, Process Model.

INTRODUCTION

Efficient design management is essential to enable designers to proficiently respond to the competitive construction industry and the clients' requirements. Proper administration of the design phase is critical to ensure compliance with the standards, effectively translate the clients' value prepositions into successful projects, and satisfy cost and time constraints. On the other hand, changes in the design phase or late information sharing results in drastic delays and problems downstream in the construction phase. The research described in this paper focuses on the design phase

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of construction projects, that when managed properly, has high positive impacts on the project's downstream by saving time and preventing rework and cost overruns. The design phase requires specific inputs to generate the required outputs. In fact, it is commonly perceived that the design process is solely concerned with the thought process that transforms these inputs into outputs and neglects the key role of information exchange, the 'fuel of design', between the different members of the design teams (Baldwin et al., 1999). The majority of the information shared by the design participants rarely ends up actually adding value to the project despite the increased amount of information being available for use (Phelps, 2012).

CONCEPTUAL AND SCHEMATIC VS. DETAILED DESIGN MANAGEMENT

This paper aims at understanding and comparing the information flow processes on traditional 2D CAD projects and BIM-based projects under traditional project delivery to identify where failure in communication occurs and the hurdles preventing stream-lined workflow. This research focuses on studying information flow in the conceptual and schematic design phases instead of the detailed design phase, the former two phases being very iterative in nature and muddled with much backtracking accompanying the exchange of information between design teams (Austin et al., 2001). Additionally, changes at these two stages are more frequent and have a larger overall impact on design than those at the detailed design phase (Baldwin et al., 1999). On the other hand, the detailed design phase is well structured and has more controlled information flows than earlier design phases, the latter which witness multiple design alternatives carried simultaneously (Tribelsky and Sacks, 2010). This requires proper understanding and planning of the conceptual and schematic design information flow to better manage data sharing and value generation.

TRADITIONAL 2D CAD VS. BIM INFORMATION FLOW

BIM can be used as a noun to mean a building information model, an n-dimensional model which is a compilation of building information of interrelated objects. One might confuse a BIM to a regular 3D model; the latter however does not contain any smart information as it is just a 3D representation tool. Moreover, BIM can be used as "Building Information Modeling" referring to the process of using the provided model and building information to simulate and help perform real activities involved in the project (Eastman, 2008). The strength of BIM, which many users have not yet realized as they think of BIM as just a "tool or software" rather than a "process", lies in the collaboration that BIM allows and requires between the stakeholders throughout the project's life cycle (Azhar, 2011). The major contributor for the waste of information on projects is ineffective information sharing and flow. On traditional projects, the information flow between the players and project stages is jumbled. However, on BIM based projects, the interaction is more flexible and overlapped where information is aggregated and shared transparently between the different users. BIM streams information sharing of proposed designs that enable different design teams to more easily collaborate using a 'live' version of the building model instead of working in silos and snapshots. This way users can assess the impact of changes more realistically on the overall design and in real-time rather than experience late obsolete data hand-offs, back flows, and rework.

In the lean environment, it has become generally recognized that planning and managing the design process can improve project efficiency and client satisfaction. However, methods pertaining to the design management focused on the detailed design phase (Austin et al., 1999). Furthermore, research on BIM information flow and modeling the conceptual and schematic design stage is very limited, and models do not explicitly incorporate design deliverables and participants in their scheduling process. In this respect, this research effort aims at providing a comprehensive information flow process modeling of the conceptual and schematic design stages of both traditional 2D CAD and BIM-based projects. In addition, it provides a thorough comparison of both models to highlight problems in the traditional 2D CAD design processes and the benefits of BIM use making the design phase lean.

RESEARCH METHOD

This research aims at understanding and comparing the information flow in the conceptual and schematic design phases of both traditional 2D CAD and BIM-based projects under traditional project delivery (D-B-B contract type). The specific aims identified in this study include: (1) understanding how information flows on traditional 2D CAD and BIM-based projects in the conceptual and schematic design phases, (2) comparing the captured information flow between traditional 2D CAD and BIM-based projects to realize the benefits of BIM use on projects, (3) assessing the potential design process improvements resulting from the use of BIM in the conceptual and schematic design phases, and (4) highlighting where failure in communication occurs and the hurdles preventing stream-lined workflow.

To achieve the above research targets, the following research methods were followed: (1) reviewing previous research work on traditional 2D CAD design phases, (2) interviewing design professionals about the information exchange and flow between the design participants on BIM-based projects, and (3) compiling this gathered data and modeling the flows in cross-functional (swim-lane) diagrams.

PREVIOUS RESEARCH WORK ON TRADITIONAL 2D CAD DESIGN PHASES

A thorough revision was conducted on previous research work that studied data flow in the building design process, the generation of data flow diagrams (DFD), and the utilization of design structure matrices (DSM) to plan and manage the design phase (Baldwin et al., 1999). Other studies targeted design iterations that were identified by DSM and modeled through discrete-event simulation (Wang et al., 2005). Moreover, other research efforts focused on extensive measuring of information flow in the detailed design phase that aimed at identifying rework and bottlenecks occurring on traditional 2D CAD projects (Tribelsky and Sacks, 2010). This paper aggregates some of the stated research work and comes out with a traditional 2D CAD design phase process model. This model not only shows the sequence of information exchange in the conceptual and schematic design phase, but also divides the information flow between the cross-functional participants, and presents the data deliverables generated by the cross-functional teams design processes in order to highlight potential design iterations, rework, delays and idle time, and unnecessary repetitive processes.

INTERVIEWS WITH DESIGN PROFESSIONALS TO GENERATE THE BIM-BASED AND VALIDATE THE 2D CAD PROCESS MODELS

In order to model the flow of information in the BIM-based design phase, research work on BIM collaboration and the roles of participants in the modeling process were reviewed, after which a preliminary process model was generated. The authors then consulted with design professionals in the BIM field for their feedback on the preliminary process model and interviewed them to further develop it. The design professionals have over 20 years of experience working at major architectural/ engineering firms in the Middle East and the US. These firms use BIM on medium sized residential buildings, large complex structures such as stadiums and convention centers, as well as universities, airports, hospitals, and governmental facilities. Moreover, to validate the data in the process model of the traditional 2D CAD design phase information flow, the design professionals were also asked to provide their feedback on the process model. The comments targeted the roles of the cross-functional teams, the data deliverables of each design stage, and the interaction and information exchange between the teams.

MODELING THE PROCESS OF INFORMATION FLOW INTO SWIM-LANE DIAGRAMS

After compiling the data of previous research work on traditional 2D CAD design phases, and interviewing and consulting with BIM design industry professionals, two cross-functional (swim-lane) diagrams were created for both project types. The choice of swim-lane diagrams is not to only help visualize how the information flows on each project, but to clearly identify how this information is exchanged between the different design players (architects/ designers, structural/ civil engineers, MEP engineers), and to highlight the information deliverables that flow on projects. These information deliverables are functional primitive tasks (FPT), which are the low level deliverables of a design process such as generating plans and sections, and they exclude higher level activities such as developing and coordinating design concepts. The latter activities, in fact, precede the FPTs, and are presented as processes and sub-processes that generate these FPTs. Each model will be discussed in more detail in the subsequent sections of this research paper.

PROCESS MODELS AND EXPLANATION

TRADITIONAL (2D CAD) DESIGN PHASE PROCESS MODEL

The traditional (2D CAD) design phase information flow was modeled in cross-functional (swim-lane) diagrams. As mentioned earlier, the choice of swim-lane diagram is for the fact that it helps present three things simultaneously: (1) information flow, (2) clear information exchange between the different participants, and (3) data deliverables resulting from each design process. The swim-lane diagram shown in figure 2 is divided horizontally into three lanes (architect/designer, structural/civil engineer, and MEP engineer). Vertically, the diagram is divided into four phases. The first phase is the conceptual design phase, followed by review and iterations (rework) period when the conceptual design phase tentatively ends, and once the review period and any rework has been performed and accepted by the owner, the schematic design phase is triggered. In a similar fashion, it is followed by a review and iterations period once the schematic design phase tentatively ends. After receiving the approval of the owner, the design teams can then proceed to the detailed design phase which will not be modeled since it is more stream-lined and straightforward. The architects start by developing the design concept and then generate information deliverables like preliminary massing and orientations of the project. These deliverables are collected as documents, and after the architect concept design ends tentatively, they are then passed on to the structural/ civil engineers who have been waiting to receive these documents and experience delays and idle time. Similarly, the structural/ civil engineers proceed with developing their concept design and generate information deliverables. Meanwhile, the MEP engineers after also waiting to receive the data deliverables from the architects, start developing their concept design as well. Only after the teams have finalized their preliminary concept designs, silos of information documents can then shared in iterative feedback loops between the different teams to perform the necessary adjustments. Traditionally, the teams have to submit their information deliverables to the architects and owners for their decision, which results in either the acceptance (with comments) or rejection of the design concept documents. In the case of rejection, which normally comes late as it waits for the complete design input, the structural/ civil, MEP engineers, and architects have to perform adjustments and rework in the design process and go back again through several iterative loops before the design finally gets accepted. Upon the owner's approval, a final concept design report is generated to proceed with the schematic design phase. This phase proceeds in a similar manner as the concept design and includes several iterative and feedback loops, idle time and delays, rework and adjustments until the approvals of the architects and owners are received.

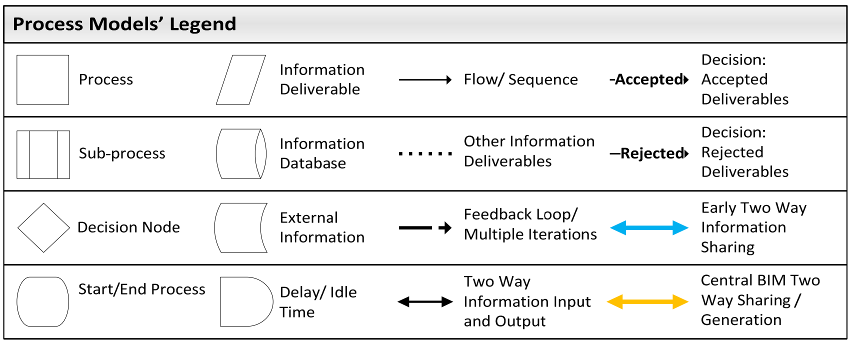

Figure 1: Components of the Process Models of the Traditional and BIM-based Design Phases

BIM-BASED DESIGN PHASE PROCESS MODEL

The swim-lane diagram shown in figure 3 is divided horizontally like the traditional 2D CAD design phase information flow swim-lane diagram. However, vertically, only the conceptual and schematic design phase are present as the information coordination, sharing, and owners' feedback happen during each of these phases and do not have to wait till the design is complete.

The concept design phase starts by developing the architectural concept in the BIM environment and generating deliverables that are incorporated into the building information model. Unlike the traditional 2D CAD design phase, the structural/civil

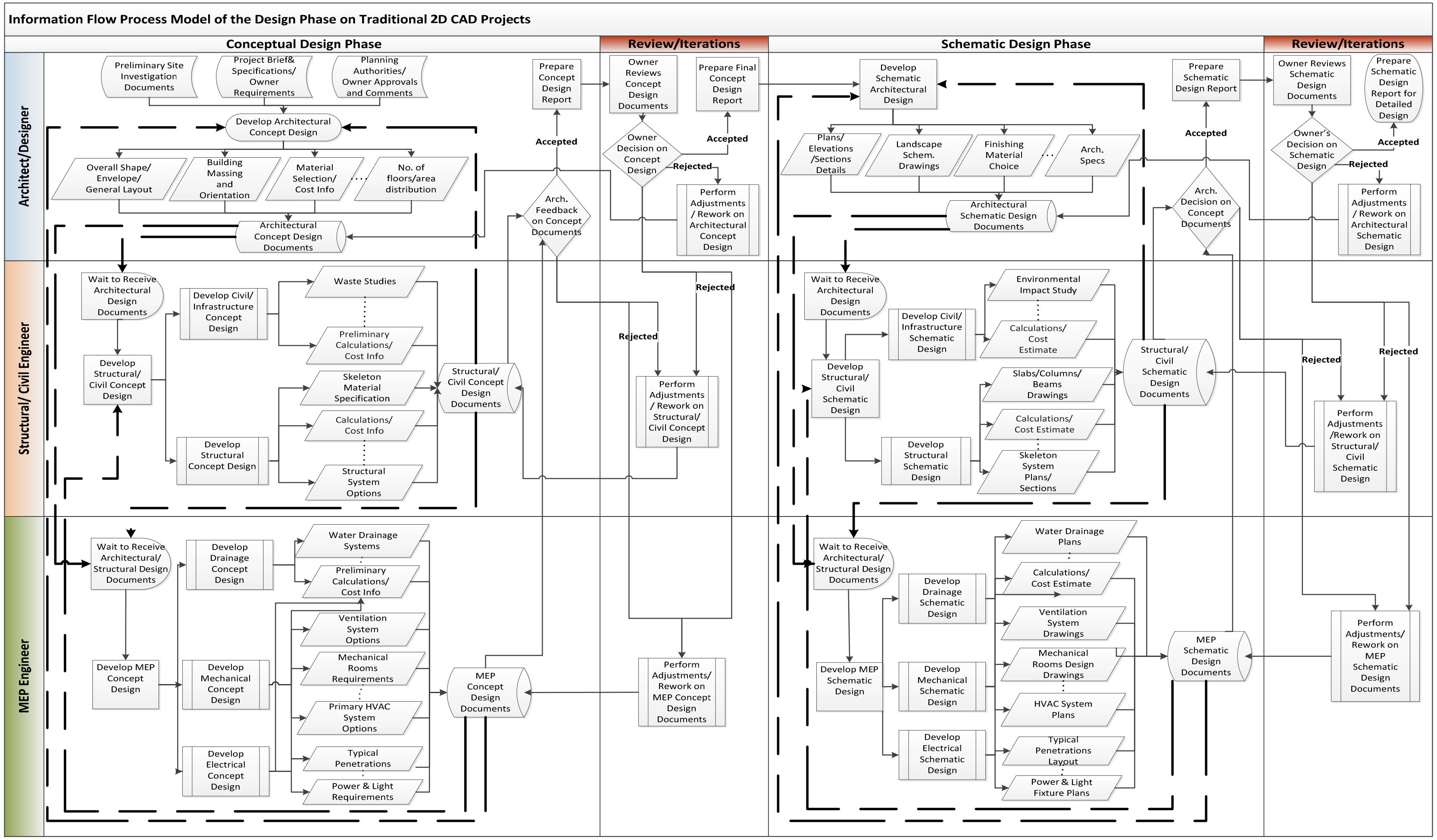

Figure 2: Information Flow Process Model of the Design Phase on Traditional 2D CAD Projects

and MEP engineers do not have to wait until the completion of the architectural design concept to proceed. Instead, early and easy data sharing is possible before data completion, thus the three cross-functional teams can develop their design concepts simultaneously. These concepts are modeled in the BIM environment, and result in individual comprehensive building information models that are integrated into one central model. This central model and individual models allow two-way information sharing between the different design participants in real-time as well as prompt adjustments of the model information after integrating and coordinating all the data. In addition, the owner can get on board during the design concept development to provide his early feedback on the design criteria as the required deliverables can be extracted from the building information models at any time. This avoids the late "acceptance or rejection" decisions which result in massive time and cost consuming rework and countless design iterations as it happens on projects not using BIM.

After the completion of the conceptual design phase, there is no need to start over and generate new models to develop the schematic design process. Instead, the previous individual building information models are further detailed in accordance to the required level of development (LOD) of the schematic design phase. This in turn saves time of starting over and wasting time. The schematic design process then proceeds in the same logic of the previous design phase.

INFORMATION FLOW COMPARISON AND DISCUSSION

There is a broad spectrum of possible BIM uses and benefits on construction projects. When BIM is realized as a process extending throughout the lifecycle of the project, instead of just a tool, the benefits can be realized. Along with its powerful ability to provide n-dimensional visualizations, scheduling and cost estimations, different building analysis (structural, civil, energy, safety…) and others, the power of BIM lies in its ability to make an integrated and collaborative approach to design and construction possible. In lean terms, effective communication, collaboration, and working towards a common goal are keen on generating value for the owner and reduce, if not eliminate, waste from the processes involved in delivering the project. To gain a better realization of these benefits and how BIM enables a lean design phase, a comparison between the two information flow process models is conducted and the results are discussed:

- Timely Incomplete Design Information Sharing and Communication: In traditional 2D CAD design, the different participants have to wait for each other's design completion; the data deliverables are piled in silos before they can be exchanged between the design teams. In such case, data can become obsolete, in other words, the data goes to waste. In contrast, in BIM-based design, early and timely exchange of incomplete information between participants IS enabled by sharing and integrating the building information models of the teams at any point in time. This allows real-time design adjustments and development. The information is then always up-to-date, and the clear design intent visualization facilitates communication between players and allows for continuous information flow instead of interrupted batch flow.
- Idle Time: The swim-lane diagram of BIM-based design phases clearly shows the reduction in delays as opposed to the traditional design phases. As

mentioned above, since data sharing can occur even before the design is complete, there is little or no idle time for the different teams when waiting to receive complete data information from each other. Idle time is a large source of waste in design and is a critical factor to be eliminated to prevent delaying the design generation phase requested by the owner. Through the use of BIM, such idle times and unnecessary delays of waiting are minimized or eliminated.

- Owner Involvement and Value Generation: BIM enables the involvement of the owner/owner's representative and have him on board throughout the design progress by the ability to extract any design information when required from the integrated or individual models. In this respect, the owner's early feedback is of high value as it eliminates the late decision on the design data which, if rejected, results in rework, cost and time waste. Moreover, by involving the owner continuously as the design progresses, his value preposition will be properly translated throughout the project life cycle.
- Iterative Loops and Rework: Iterative loops are a result of limited communication and information sharing. When data is shared in batches in an untimely fashion, it tends to go back and forth between the various design players in several loops before the design deliverables can exit the loop upon the acceptance of the architect and owner. When rejected, which is normal in design processes, the design deliverables have to be reworked. Since the deliverables are in 2D CAD, any adjustment of a certain concept or a drawing perspective, has to be reflected in all other trades/disciplines and views. However, by using BIM, this can be done automatically by modifying the model once in one view and all the other views are automatically modified, and the other involved players can be instantaneously notified of the required adjustments on their behalf (Hardin, 2009). This benefits the project reducing negative iterations and rework, thus saving time and preventing cost overruns.
- Quality of Design: Designers can make use of BIM to explore alternative concepts, conduct value engineering and optimize their designs. BIM enables collaboration among the different participants and allows data input from everyone which generates a complete picture of the owner's design intent in everyone's mind. In this regard, the architects and engineers will work towards a common design of higher quality instead of having segregated ideas and lost quality achievement along the jumbled iterative traditional design phase.
- Future work: simulation of information flow

The process models can be used as a source of data for other tools and applications to manage the design phase of construction projects in terms of cost, time, and resources. To quantitatively assess the effectiveness of design management and to measure potential time and cost savings realized from the use of BIM on projects, the authors will further develop simulation models. These models transform the static process models into dynamic models where the user can immediately observe the changes with time advancement and while interacting with the model (Baldwin et al., 1999). For this purpose, the simulation models of both design phase types will be applied on case studies to assess the potential design process improvements resulting from BIM use.

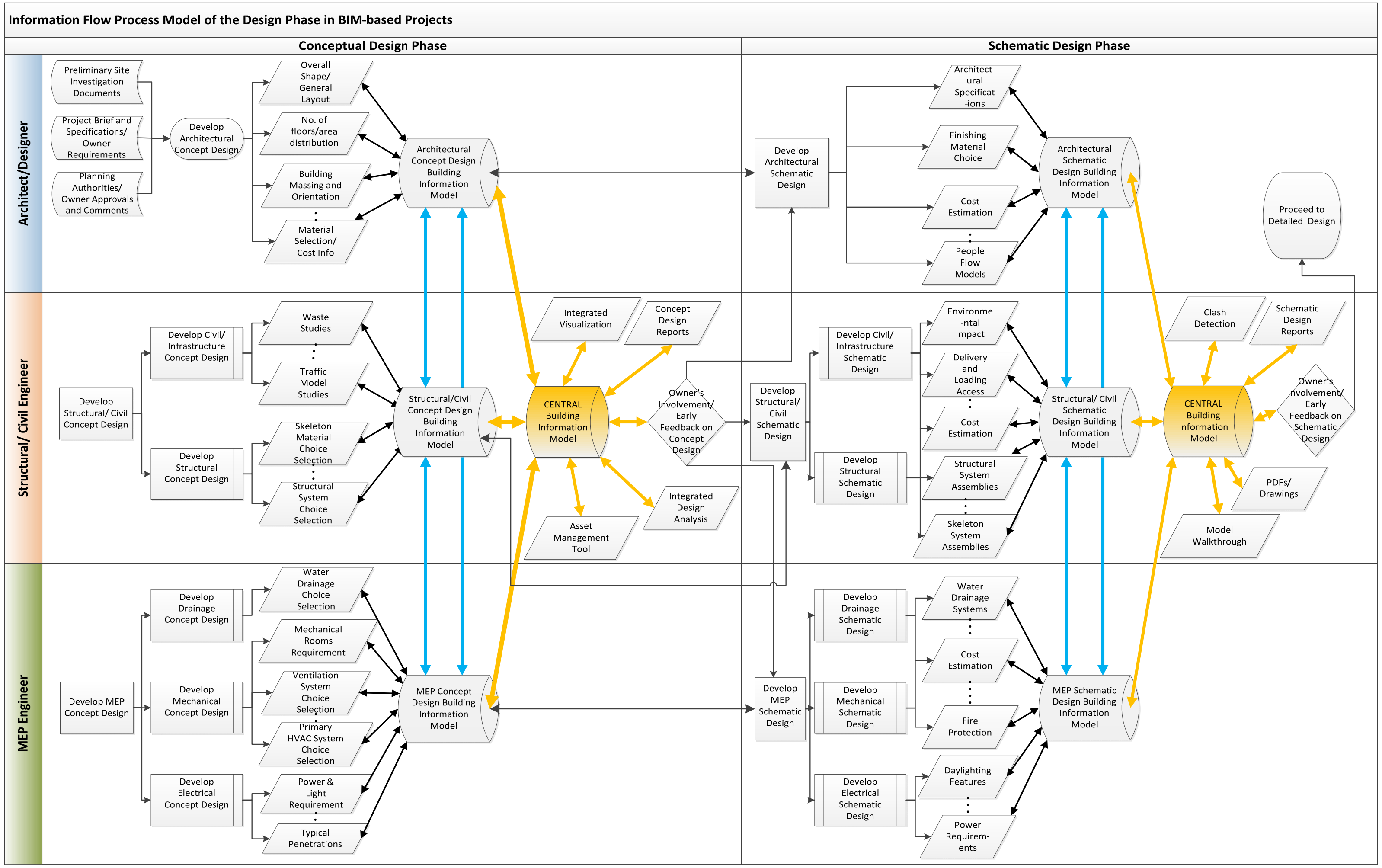

Figure 3: Information Flow Process Model of the Design Phase in BIM-based Projects

CONCLUSION

Extensive research and industry practice recognize the essential need for proper design process management. Before implementing lean principles and BIM to improve the design phase, it is necessary to realize that the major source of information waste is sub-optimal information sharing, and to thoroughly understand the iterative nature of the conceptual and schematic design stages. It is also necessary to highlight the drawbacks in the traditional design practice across the industry.

In this regard, two process models for the information flow in traditional 2D CAD and BIM-based design phases are modeled in cross-functional (swim-lane) diagrams. The two models are then explained and compared to realize the benefits of BIM use and to highlight the obstacles preventing stream-lined information flow. The results of the comparison show a high ability for transforming the traditional design phase into a lean design process by the use of building information modeling.

Project success is getting increasingly reliant on the entire information channel between the entities of its supply chain. By analyzing the interactions within the participants and the respective information exchange, the required interventions and desired changes can be implemented. Such changes can boost connectivity between project players to give way to a free flow of information throughout the entire project life span, which transforms its delivery into a lean and waste-free process.

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